IJRAR.ORG E-ISSN: 2348-1269, P-ISSN: 2349-5138

INTERNATIONAL JOURNAL OF RESEARCH AND ANALYTICAL REVIEWS (IJRAR) | IJRAR.ORG

An International Open Access, Peer-reviewed, Refereed Journal

Coal Mine Overburden Waste as a Sustainable Substitute for Fine Aggregates in Concrete.

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Abstract*:* The majority of the energy used to meet the world's current energy needs comes from coal that is mined. In terms of Indian coal mines, and specifically the Jharia coal field, the majority of the mines are open cast. The overburden, which is largely made up of sandstone, shales, and clayey minerals, must be removed in the course of mining the coal seams. This not only occupies significant land but also degrades its quality. Loose materials from these dumps can easily become airborne, posing environmental risks. Extraction of sand from rivers causes various problems. So, it is important to notify different alternatives that are abundant and eco-friendly in nature. This study centers on investigating the feasibility of using sandstone, a waste product from coal mining, as a substitute for traditional fine aggregate in concrete. Laboratory analysis revealed that sandstone possesses physical properties such as water absorption, moisture content, and fineness modulus that closely resemble those of typical fine aggregate. Based on civil engineering standards, this paper provides the overburden waste's geotechnical characteristics. This project uses OB trash as the fine aggregate for casting concrete. Fine aggregate was replaced with sandstone at levels of 25%, 50%, 75%, and 100%. Compressive strength tests were conducted on concrete cubes at 3, 7, and 28 days, while split tensile and flexural strength tests were performed at 28 days. The strength was found to be increasing with increase in the sandstone content. Fine aggregate replaced by 50% sandstone gave higher strengths among all the replacements for the compressive, split tensile and flexural strengths. This study can assist civil engineers in selecting an appropriate substitute for river sand, whose extraction causes numerous environmental issues.

Index Terms - Mine Waste, Overburden dump, Natural fine aggregate, Sustainable construction

1 INTRODUCTION

An essential energy source is coal. About one-third of the world's power is produced by coal, which is also essential to numerous industries like iron and steel. The majority of emerging and underdeveloped nations rely heavily on coal to meet their energy demands. India uses roughly 11.3% of the world's coal, making it the second-largest coal consumer after China. India is the world's second-largest producer of coal. About 55% of India's energy demands are met by coal. Coal accounts for over 70% of electrical production. Underground mining and open cast mining are the two types of coal mining. Open cast mining is appropriate for shallow coal seams, while the underground approach is appropriate for deeper coal seams. Due to lower production costs and less waste, open cast mining accounts for 93.26 percent of production in India. Coal may only be extracted in open-pit mining after layers of soil, stone, etc. have been removed; this layer is known as overburden. It produces more coal than two times as much, and it is continuously increasing each year. Coal In this situation, reducing mine waste is a good idea, and one way to do this is by using overburden trash as building material for civil buildings and as backfill for underground mines. Numerous studies have demonstrated the use of mine waste in the production of concrete paving blocks and bricks for building.

Overburden dumps are tough to manage due to land scarcity and height stability concerns. Overburden garbage includes loose, fine material that is very likely to be carried by the wind. These are dispersed over productive land and impede plant development. Due to the emission of particulate matter, gases like methane, Sulphur dioxide, and nitrogen oxides, and suspended material, it pollutes the air and results in water contamination. Heavy metals and other contaminants that leach into the ground can contaminate local drinking water, resulting in groundwater pollution and harm to the flora. The cumulative impact of overburden dumps extends beyond just land and air pollution; it has far-reaching consequences on local ecosystems and biodiversity, disrupting the delicate balance of flora and fauna.

Studies were carried out on various industrial wastes as partial replacements for aggregate or cement in concrete or mortar. These studies included the following waste materials: recycled aggregate, blast furnace steel slag, plastic waste, coral aggregates, rubber aggregate , fly ash , thermoplastic waste aggregate , construction and demolition waste , and bauxite residue. Additionally, several studies have shown the use of mine waste in brick making for construction purposes and in making concrete paving blocks. Overburden (OB) consists of sandstones, carboniferous shale, mudstone, greystone, and silty soil as primary constituents, and these may vary depending upon the local geology, It's a serious situation. Growing demand is producing social issues, environmental damage, and sand shortage worries. Using coalmine overburden waste rock as a substitute for natural sand in construction can help address sustainability challenges in both building and mining industries. The waste rock (cradle) processing to the final product (gate) involves transportation to the processing plant, crushing, screening, washing, and transportation from the processing plant to the client or project site. River sand excavation harms the environment and is also in short supply and can't meet our growing needs. Using mine waste in various industries can create jobs and mitigate this issue. In countries like India, the scarcity of high-quality natural sand threatens the environment and society, leading to water-related problems, erosion, and agricultural impacts. This study first involved evaluating the physical, chemical, and mechanical strength parameters of OB for potential use in concrete. Then, it examined the strengths developed when replacing fine aggregates. Based on these results, OB is found to be suitable as a building material, meeting both the strength and durability criteria.

2. MATERIALS AND METHODOLOGY

2.1 RAW MATERIAL

The Overburden sampling is carried out within the coal mine located in the Lodna area of the Jharia Coalfield, situated in Dhanbad, Jharkhand. Lodna area is located at 23.72011°N, 86.41059°E. It is Situated in the central region of the Jharia coalfield, approximately 15 kilometers to the south of Dhanbad Junction, this underground mine contains significant reserves, including 8.276 million tonnes of coking coal and 98.219 tonnes of non-coking coal. The collection process involved obtaining samples from five distinct locations within a specific overburden area. These samples, totaling approximately 50 kg in weight, were placed in plastic gunny bags while ensuring that any extraneous rocks were excluded.

To prepare the samples for experimentation, they were meticulously mixed and crushed to reduce rocks and lumps into finer particles. This procedure facilitated the conversion of larger rocks into smaller, more suitable sizes for research purposes. Following this, the samples underwent a thorough washing with water to eliminate the clay component from the overburden material. The separation of overburden sand from clay was accomplished through a sedimentation technique, and the sand was subsequently dried in natural sunlight. The resulting material was identified as overburden (OB) sand, which constituted roughly 65% of the original overburden material obtained from the dump site.

Fig 1. Sample Collection Site

Fig 2. Sampling spot

2.2 SPECIFIC GRAVITY

The specific gravity of a material serves as an indicator of its strength and overall quality. A lower specific gravity suggests that the aggregate is less robust compared to an aggregate with a higher specific gravity. Additionally, specific gravity is utilized in determining the void ratio and density of the aggregate through calculations.

$$\text{Specific gravity} = \frac{(W2-W1)}{(W2-W1) - (W3-W4)}$$

2.3 SIEVE ANALYSIS

Aggregate grading refers to the distribution of particle sizes within an aggregate. When particles are uniformly sized, the aggregate will contain more voids, which provides insight into the void content. The goal in sizing aggregate particles is to ensure that finer particles fill the spaces left by the coarser ones. The quality of fine aggregate greatly affects concrete's packing density, void content, workability, and strength. A well-graded aggregate with high packing density requires less paste, leading to improved workability and more stable concrete while reducing issues like bleeding, creep, and shrinkage. Conversely, if the fine aggregate is excessively fine, it will demand more water.

To determine the particle size distribution of fine aggregate, the IS:2386 (Part 1) - 1963 standard method is recommended. According to the percentage of fine aggregate that passes through various IS sieves, IS:383 - 2016 classifies fine aggregate into four zones: I, II, III, and IV, with a range from 10 mm to 150 μm. The fineness of fine aggregate gradually increases from grading zone I to zone IV, and the proportion of fine to coarse aggregate should decrease accordingly

Fig 3. Sieve analysis

Fig 4. Sieves of different sizes

2.4 BULK DENSITY

Bulk density, dependent on aggregate shape, texture, and gradation, indicates the amount of empty space within the aggregate material. Hence, how aggregates are sized and distributed is vital for concrete, particularly high-strength concrete. Factors such as the size range of particles, their shape, and the moisture they contain, all play a role in determining bulk density.

The bulk densities of saturated, surface-dry loose, and compacted OB sand were calculated to be 1468.54 kg/m3 and 1645.57 kg/m3, respectively. OB sand has a bulk density that is comparable to that of natural sand.

2.5 MOISTURE CONTENT

Moisture content holds paramount importance in the construction industry, particularly when it comes to sand. Sand particles tend to be enveloped in a delicate layer of moisture that clings to their surfaces. Because of its finer particle size, sand has a higher propensity to absorb moisture from the surrounding environment compared to coarser aggregates. The construction sector places special emphasis on monitoring and controlling the moisture levels in sand due to its crucial role in cement production.

$\boldsymbol{Moisture\ Content}=(\boldsymbol{w2}-\boldsymbol{w3})/(\boldsymbol{w3}-\boldsymbol{w1})$

2.6 COMPACTION TEST

Compaction involves the action of enhancing the density or unit weight of soil by exerting external forces, which, in turn, decreases void spaces and maximizes the proportion of solid particles within the soil. In simpler terms, it's the deliberate process of making soil denser by reducing empty spaces and increasing the concentration of solid particles through external pressure.

2.7 PERMEABILITY TEST

To determine the settlement rate of structures, we use the coefficient of permeability. In the case of optimal compaction, 310 milliliters of water (which is the Optimum Moisture Content, OMC) are mixed with 1 kilogram of soil. The falling head test is employed to calculate permeability

2.8 ORGANIC IMPURITIES

The presence of organic contaminants, such as decomposing plant matter, in the aggregate can potentially delay the setting and hardening of concrete by interfering with the hydration process. To assess the presence of organic substances in the OB sand, the method outlined in IS:2386 (Part 2) - 1963 involves observing the color of the liquid above the sand. In the case of OB sand, it was found to be free from organic impurities.

2.1 COMPRESSIVE STRENGTH

In this experimental study, we separately utilized river sand and OB (overburden) sand to create M 20 concrete specimens. To ascertain the concrete's appropriate strength, the compressive strength was determined by taking the average of three individual samples. The examination of these samples was conducted at both 7 days and 28 days of the curing period. It was observed that the concrete's strength exhibited a notable improvement as the curing duration extended. To establish the compressive strengths of the concrete samples produced from both OB sand and river sand, the absolute strength of each sample was determined by by calculating the average from the three individual samples.

Fig 5. Fully automatic compression testing machine

3 INVESTIGATION AND RESULTS

3.1 SPECIFIC GRAVITY

Table 1 Specific gravity values calculation for OB sand

		1	2	3
1	Weight of Pycnometer (W_1)	638	638	638
2	Weight of Pycnometer + Dry sample (W_2)	810	805	830
3	Weight of Pycnometer+ Sample+ Water (W_3)	1620	1614	1632
4	Weight of Pycnometer + Water (W_4)	1510	1510	1510
5	Specific Gravity	2.78	2.65	2.74

- Average specific gravity of overburden sand is calculated to be 2.72 while the average specific gravity of river sand is calculatedas 2.65, which is close to river sand. So, it could be a replacement of river sand.

3.2 SIEVE ANALYSIS

Table 2 Sieve analysis of overburden sand

IS Sieve	Weight retained (g)	Percentage weight retained (%)	Percentage cumulative weight retained	Percentage passing (%)
4.75 mm	32	3.2	3.2	96.8
2.36 mm	125	12.5	15.7	84.3
1.18 mm	168	16.8	32.5	67.5
600µ	258	25.8	58.3	36.7
300µ	314	31.4	89.7	10.3
150µ	68.5	6.85	96.55	3.45
pan	34.5	3.45	100	0

Table 3 Sieve analysis of river sand

IS Sieve	Weight retained (g)	Percentage weight retained (%)	Percentage cumulative weight retained	Percentage passing (%)
4.75 mm	10	1	1	99
2.36 mm	55	5.5	6.5	93.5
1.18 mm	160	16	22.5	77.5
600 µ	360	36	58.5	41.5
300 µ	320	32	90.5	9.5
150 µ	85	8.5	99	1
pan	10	1	100	0

- Fineness modulus of OB sand is 2.95 whereas for river sand FM is 2.78.

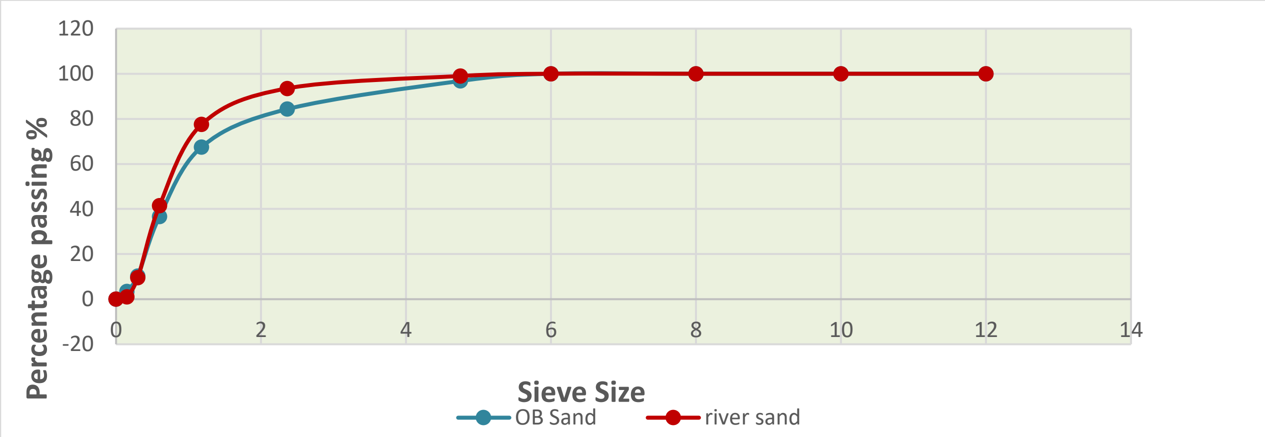

Fig 6. Particle Size Distribution Curve of OB sand and River sand

3.3 MOISTURE CONTENT

Table 4 Moisture Content Calculation

S. Nn	Sample	Weight of container (W1)	Weight of container+ Sample (W2)	Weight of oven dried container filled with soil (W3)	Moisture content
1	OB Sand	80.56	144.92	144.02	1.418%
2	River Sand	65.39	145.8	145.15	0.82%

3.4 COMPACTION TEST

Table 5 Compaction test for OB sand

Water Content	Dry density
4.36	1.61
6.85	1.70
7.56	1.77
8.36	1.80
9.96	1.83
12.85	1.78
14.38	1.75

Table 6 Compaction test for River sand

Water Content	Dry density
5.9	1.521
6.4	1.546
7.86	1.601
8.63	1.637
12.54	1.592
15.24	1.581
17.56	1.553

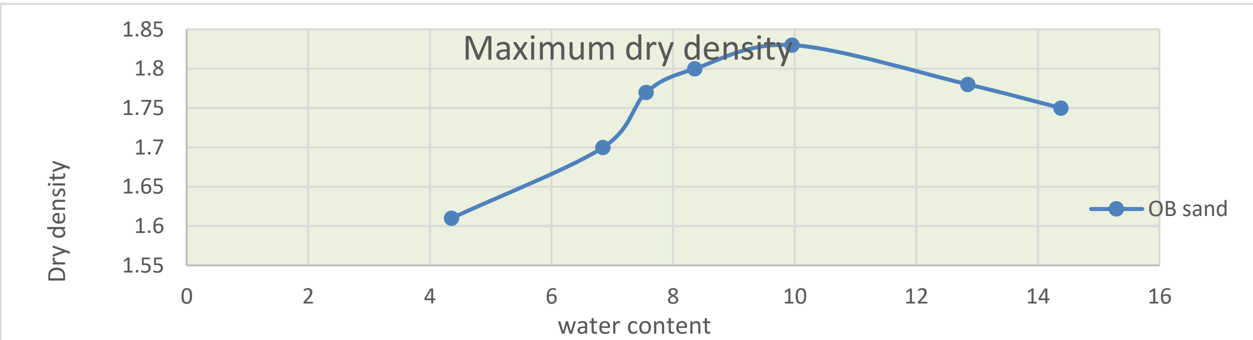

Fig 7 Compaction of OB sand

3.7 PERMEABILITY

Table 7 Permeability Test Result

S No	Sample Name	Coefficient of permeabilitycm/sec
1	OB sand	3.52×10^{-5}
2	River Sand	4.85×10^{-5}

3.8 COMPRESSIVE STRENGTH TEST RESULT

This section presents the outcomes of laboratory experiments, with accompanying tables and graphs for visual representation and data analysis.

Table 8 Compressive strength variation

S.No.	% of Replacement of Sandstone	Compressive Strength (N/mm^2)		
		3 Days	7 Days	28 Days
1	0%	13.70	17.20	22.50
2	25%	13.78	17.22	23.18
3	50%	14.80	17.96	23.78
4	75%	15.75	18.32	24.98
5	100%	15.12	18.10	24.33

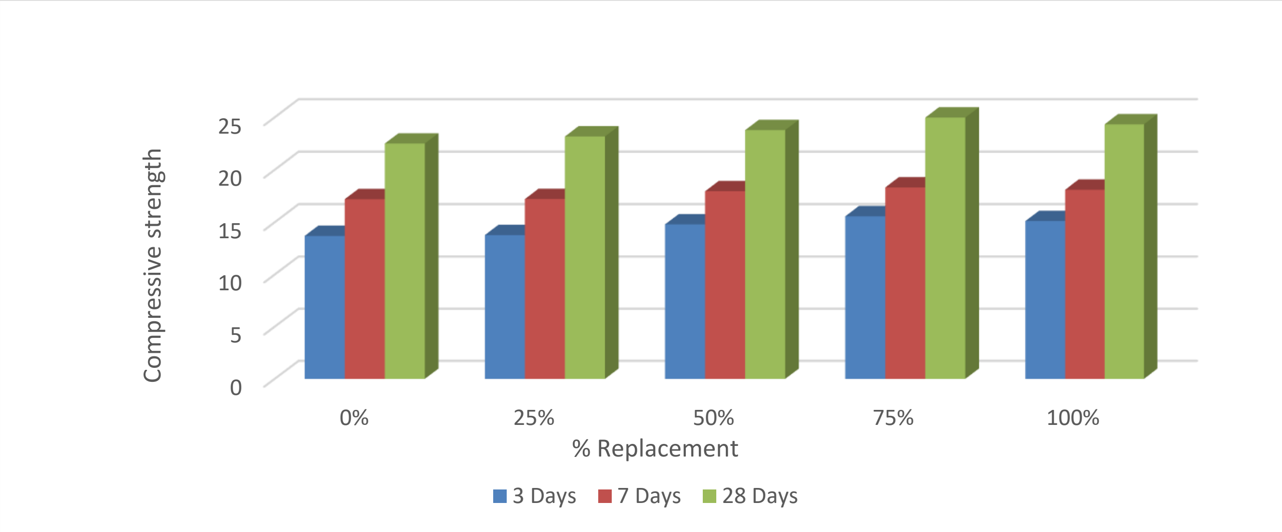

Fig 8. Compressive Strength comparison

3.9 SPLIT TENSILE AND FLEXURAL STRENGTH TEST RESULT

Table 9 Split tensile and flexural Strength variation

S.No.	% of Replacement of sandstone	Split tensile strength	Flexural strength
		(N/mm^2)	
		28 days	28 days
1	0%	3.18	3
2	25%	3.20	3.12
3	50%	3.35	3.3
4	75%	3.46	3.6
5	100%	3.39	3.41

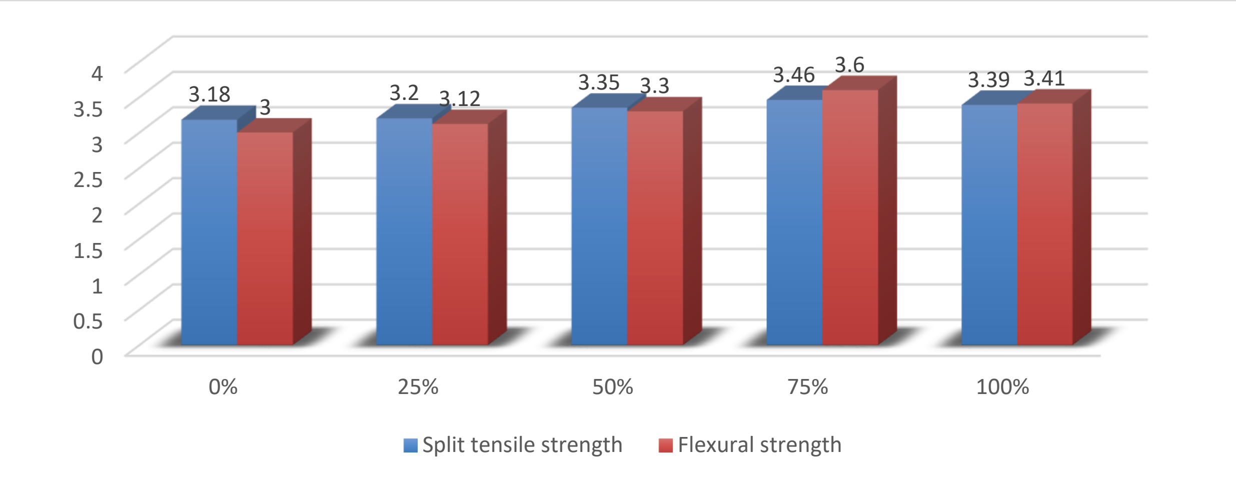

Fig 9. Split tensile and flexural Strength comparison

CONCLUSION

The following conclusions can be drawn from the Experimental Investigation:

- In comparison to river sand, OB sand has a specific gravity of 2.72. These have nearly identical specific gravities. Because OBsand contains more clay than river sand, it has a somewhat higher moisture content than river sand. Moisture content of OB sand calculated as 1.418% and that of sand is 0.82%. Moisture will be absorbed and accumulated in a region where clay is present. Thereis no clay present in river sand. Because of this, river sand's permeability is more important than OB sand.

- The OB sand with a fineness modulus of 2.95 demonstrates its suitability as an excellent substitute for fine aggregate in construction applications.

- Maximum Dry Density (MDD) of OB sand is 1.83 g/cc compared to 1.637 g/cc for river sand, OB sand has a higher MDD than river sand. Because OB sand contains more silt and clay than river sand, its optimal moisture level is lower. As a result, less wateris needed to compact the soil with OB sand than with river sand.

- The specific gravity and water absorption of the OB sand closely resemble those of traditional fine aggregates, and they do not adversely affect the workability of the material.

- M 20 grade of concrete is used in this experiment. Based on the findings, both samples of OB sand and river sand offer roughly the same strength. Compressive strength of concrete cubes increased with the increase in percentage replacement of fine aggregate for 3, 7 and 28 days. The maximum 28 days compressive strength was observed at fine aggregate replaced with 50% OB sand and the strength got increased by 11.02%

- Split tensile strength and flexural strength of concrete was increased with increase in percentage of replacement of fine aggregate with OB sand. The maximum of these was observed at fine aggregate replaced with 50% OB sand. and that percentage increase in strength was nearly 8.8% for split tensile strength and 20% for flexural strength.

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